MORNINGSTAR®

Morningstar North America Industry Standard Model
Methodology

Morningstar Quantitative Research
April 2023

Contents

Jason Xie, PhD
Quantitative Analyst
jason.xie@morningstar.com

Patrick Wang, PhD
Quantitative Research Manager
patrick.wang@morningstar.com

Introduction

The Morningstar Risk Models are a suite of multifactor risk models that help investors identify and evaluate the risk of their portfolios using holdings-based analysis. Each model has a unique set of factors, which are tailored to the model asset class and region. We introduce the Morningstar North America Industry Standard Model in this document. This regional model includes the securities listed in the following exchanges: New York Stock Exchange, Nasdaq, American Stock Exchange, NYSE Arca, OTC Pink, Bats Global Markets, Toronto Stock Exchange, TSX Venture Exchange, and Canadian Securities Exchange. Morningstar North America Industry Standard Model contains 18 factors across style and sector:

- Equity Market
- Style: Yield, Size, Volatility (Standard Model), Quality, Liquidity, Value-Growth (Standard Model), Momentum
- Sector: Basic Material, Energy, Financial Services, Consumer Defensive, Consumer Cyclical, Technology, Industrials, Healthcare, Communication Services, Real Estate, Utilities

The Morningstar North America Industry Standard Model allows investors to:

- Understand the comparative risk exposure of North American equities and funds from the perspective of different styles and various sectors.
- Identify active decisions relative to a benchmark and measure the sizing of those decisions.
- Attribute portfolio total and active return and risk to different factors.
- Conduct scenario analysis and portfolio stress-testing using historical, market, and macro scenarios.

To showcase these advantages, we first introduce the model, including factor definition and model coverage. Next, we assess the model by first comparing the factor premiums with the performance of various style factor and sector index exchange-traded funds, followed by examining the factor exposure stability. Lastly, we present three risk model applications, including factor attribution, risk decomposition, and factor-mimicking portfolio analysis.

Model Highlights

1) Holdings-based analytics.

Our Risk Models allow true holdings-based analytics for funds. When looking at portfolios, holdings-based models tend to be more accurate for risk prediction, factor attribution, risk decomposition, and sensitivity analysis than returns-based models. Holdings-based models allow for the fact that securities, managed products, and portfolios may change over time. They also enable new securities or funds to be covered immediately after issuance.

2) Deep research into robust fundamentals-based factors.

Risk Models include fundamental equity factors that benefit from Morningstar's proprietary research. For example, Value-Growth Industry Standard factor utilizes the style score developed from the Morningstar Style Box methodology. Factors based on these ratings also tend to be uncorrelated with traditional risk factors, making them a complementary addition to our risk factor model.

3) We offer integrated and robust risk-analysis workflows.

While Risk Models themselves offer exposures, premiums, and forecasts, these outputs are usually most valuable when embedded within overall portfolio management workflows. Morningstar offers users the ability to decompose risk or attribute returns to factors and holdings through time and across many instruments. Morningstar also offers a full suite of scenario-analysis capabilities including historical scenarios, predefined macrofinancial scenarios, or market-driven scenarios.

Model Description

The Morningstar North America Standard Factor Model captures risk premiums across the North America region.

Model Universe

Similar to our global model, we define an estimation universe of investable companies with reliable data on which to build the model. Securities outside the estimation universe—generally illiquid assets with small market capitalizations—are relegated to the extended universe. We use only securities in the estimation universe to derive model parameters. This ensures the model parameters are not influenced by illiquid assets with unreliable data.

Exhibit 1 Estimation and Coverage Universe for the Morningstar North America Industry Standard Model

Estimation Universe	Coverage Universe
Approximately 4,500 stocks (Curated broad group of large, liquid stocks)	Approximately 16,000 stocks (Small, illiquid stocks)

Source: Morningstar Quantitative Research.

Our liquidity and market capitalization thresholds are time-varying depending on the market condition, which ensures the estimation universe selects investable securities at any time. Please see other details of the model in Appendix A.

Style Factors

The following style and sector risk factors are selected to be consistent with the Global Industry Standard Model. The style factors include the most prominent equity style factors that are widely accepted by investment professionals.

Style factors are normalized by subtracting the cross-sectional mean and then dividing by the cross-sectional standard deviation, so a score of 0 can be interpreted as the average score, and a nonzero score of x can be interpreted as being x standard deviations from the mean. The detailed description and interpretation of style factors are the following:

Exhibit 2 Style Factors

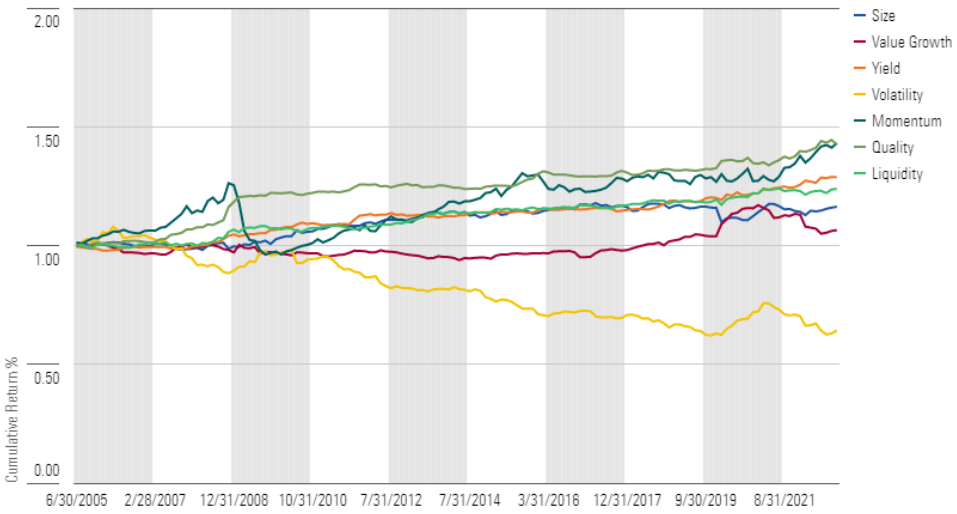
Name	Description
Yield	The Yield factor is as a total yield, which is the sum of trailing 12-month buyback and dividend yield of a company. Higher values indicate larger, positive yield exposure.
Size	The size factor is the negative value of the natural logarithm of a company's market capitalization.
Volatility (standard model)	The Volatility Composite Industry Standard factor is a combination of three volatility proxies: 1) idiosyncratic volatility (IVOL, 50%): the volatility of residual returns over the past six months; 2) total volatility (TVOL, 25%): the volatility of daily total returns over the past six months; and 3) MAX5 (25%): the average of the highest-five daily returns over the past month.
Quality	The Quality factor is calculated by equally weighting a company's trailing 12-month return on asset and trailing 12-month debt/invested capital ratio, which measure the company's profitability and financial leverage, respectively.
Liquidity	The Liquidity factor is calculated as the natural logarithm of the average trading volume divided by shares outstanding over the past 30 calendar days and measures the shares' turnover rate.
Value-Growth (standard model)	For this version of the Value-Growth factor, we use the raw style score from the Style Box as the input for calculating the value-growth exposure of stocks. The raw style score is calculated as the difference between a stock's growth score and value score.
Momentum	The Momentum factor is calculated as the cumulative return of a stock from 365 calendar days ago to 30 calendar days ago.

Source: Morningstar Quantitative Research.

From the inception of the model, our style factors have tracked the performance of each factor accordingly. The growth factor has generally performed well before 2016, with some periods of underperformance. The value factor had a difficult time before, with several years of underperformance. In particular, the value factor suffered in the years following the financial crisis, as investors favored growth stocks. However, in 2016, the value factor experienced a strong rebound, and outperformed growth stocks for several years. The North America model successfully captures that rebound of value factor. Quality and momentum are two best-performing factors, which is consistent with the industry. The quality factor has performed well. In particular, quality stocks performed well in the years following the financial crisis, as investors sought out companies with strong financials. The model successfully

captures the main events throughout the period. For example, the momentum factor dropped drastically in 2009, which is a well-documented momentum crash.

Exhibit 3 Style Factor Performance

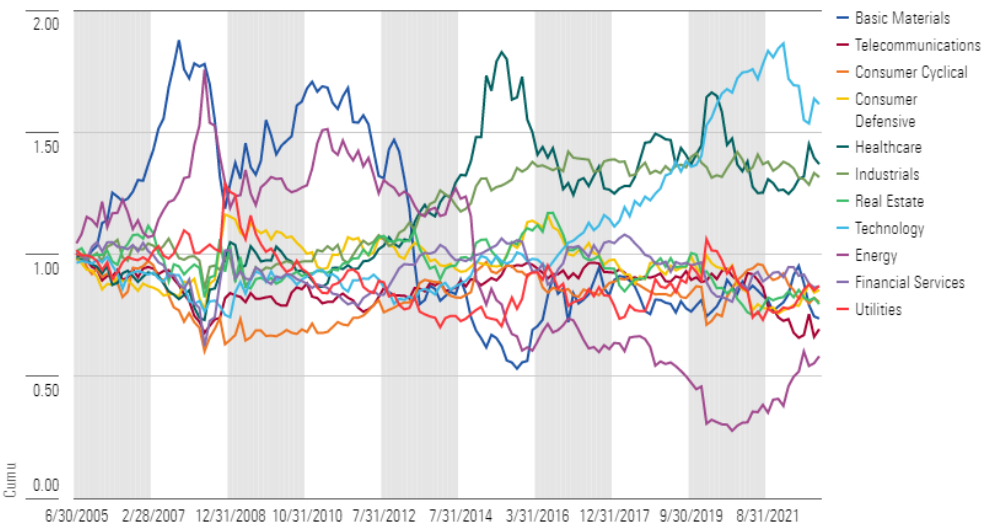


Source: Morningstar Quantitative Research.

Sector Factors

Our sector factors measure the economic exposure of a company to the Morningstar sectors. We perform a Bayesian time-series regression analysis to find the exposures of an individual company to the sector return with a prior probability based on the discrete sector classification of Morningstar's data analysts. We enforce constraints that our sector exposures, including the intercept term, must sum to 1 and must individually be between 0 and 1.

Exhibit 4 Sector Factor Performance



Source: Morningstar Quantitative Research.

Please see the detailed factor definition in Appendix B.

Model Evaluation

This section evaluates the Morningstar North America Industry Standard Model by first comparing the premiums of various style and sector factors with relevant index ETFs and then examining the stability of factor exposures of selected stocks and funds.

Comparison Between Factor Premiums With ETFs

To assess the accuracy of our model, we examine the correlation between the premiums of various style and sector factors with index ETFs. According to our constrained regression setup (please see details in Appendix C), the style factors and sector factors should measure the pure and uncorrelated returns relative to the overall market. Due to this estimation assumption, we can validate our model by comparing factor premiums and index returns. Exhibit 5 highlights the correlation between factor premiums and index ETFs. The Morningstar North America Standard Model has a large universe, especially including many small-cap stocks, compared with the indexes. The premiums of equity market, style, and sector factors are highly correlated to the returns of index ETFs (>0.7).

Exhibit 5 Correlation Between Factor Premiums and Index ETF Return

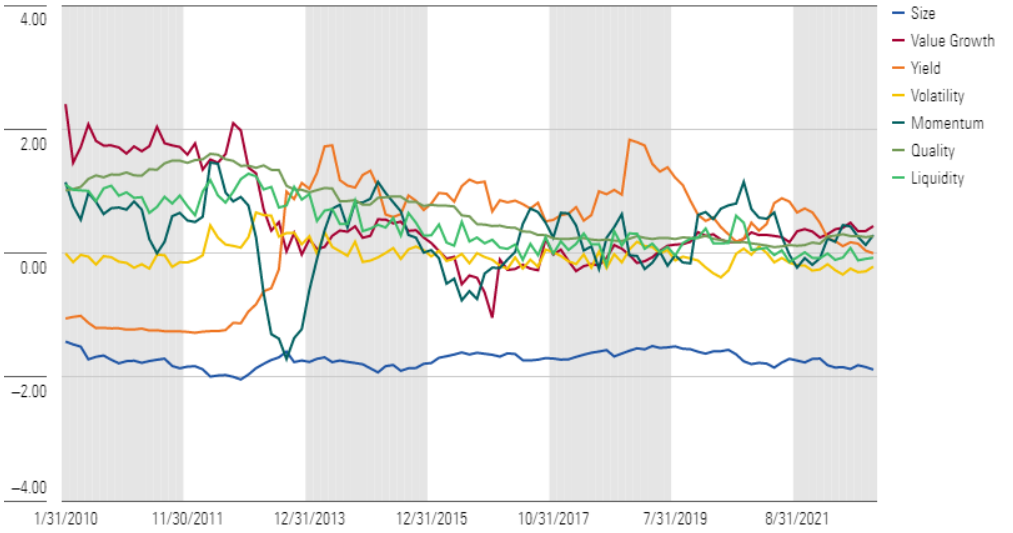
Factors	Index ETFs	Correlation
Equity Market	SPDR® S&P 500 ETF Trust	0.9650
Size	iShares MSCI USA Size Factor ETF	0.9567
Momentum	Invesco S&P 500® Momentum ETF USD	0.8457
Quality	Invesco S&P 500® Quality ETF	0.9410
Volatility	Invesco S&P 500® Low Volatility ETF	0.7027
Yield	Vanguard High Dividend Yield ETF	0.9042
Consumer Cyclical	Consumer Discret Sel Sect SPDR® ETF	0.9118
Consumer Defensive	Consumer Staples Sel Sector SPDR® ETF	0.8415
Energy	Energy Select Sector SPDR® ETF	0.8932
Financial Services	Financial Select Sector SPDR® ETF	0.9403
Healthcare	Health Care Select Sector SPDR® ETF	0.9242
Industrials	Industrial Select Sector SPDR® ETF	0.9545
Basic Materials	Materials Select Sector SPDR® ETF	0.9581
Technology	Technology Select Sector SPDR® ETF	0.9522
Utility	Utilities Select Sector SPDR® ETF	0.8237

Source: Morningstar as of November 2022.

Exposure Assessment

We examine the exposure of style factors for Apple stock and S&P 500 index ETF (SPY) from 2010 to 2022 in this section. A factor exposure measures how much an asset's return is influenced by a factor. We also modify the signs of the exposures to ensure that the premiums associated with them are positive. Exhibit 6 displays the style exposures for Apple, Inc. For example, Apple announced plans to initiate dividend payouts in 2012, which was successfully captured by the yield exposure. In 2013, Apple stock took a roller-coaster ride, falling almost 30% in the first half of the year and then gaining more than 40%, which caused the momentum factor to crash.

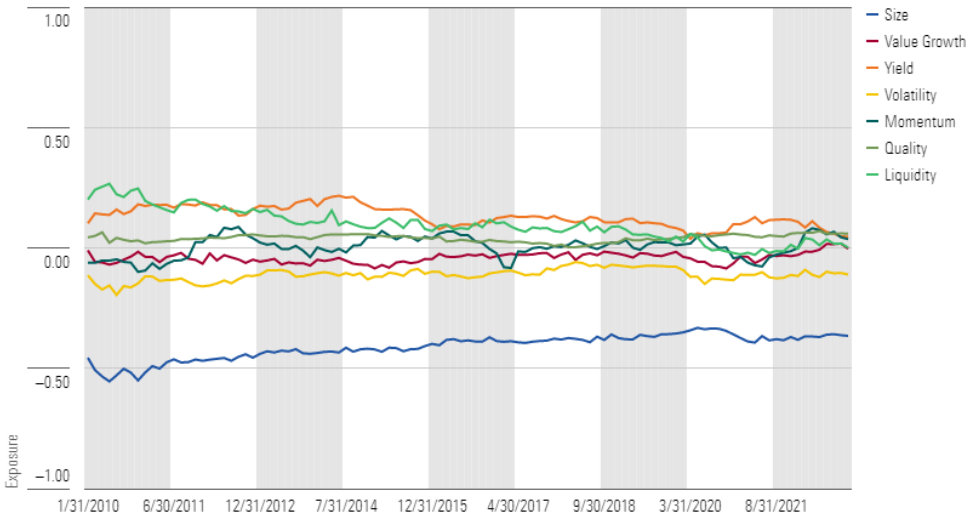
Exhibit 6 Style Factor Exposure of Apple, Inc



Source: Morningstar Quantitative Research.

In addition to asset-level exposures, Morningstar Risk Model also calculates the portfolio exposure by the product of the asset-level factor exposures and holding weights. We showcase the style factor exposure for SPY below.

Exhibit 7 Style Factor Exposure of SPDR® S&P 500 ETF Trust



Source: Morningstar Quantitative Research.

In Exhibit 7, all style exposures of SPY behave considerably more stable relative to individual assets, as expected. The momentum exposure captures the market downturn in the first half of 2020. Investors can

monitor factor exposures and make economically sound decisions about which exposures are prudent and which are worth avoiding based on the comparative risk exposures. We further investigate the stability of exposures by calculating the correlation ranks of individual asset exposure within SPY from quarter to quarter. Overall, style factors exposure for SPY are very stable, with over 0.85 correlation for most factors, as shown in Exhibit 8. Momentum factor has a lower correlation as expected, especially during the volatile period, such as the first quarter of 2020 to the second quarter of 2020.

Exhibit 8 Style Factor Exposure Stability for SPDR® S&P 500 ETF Trust

Period	Size	Value Growth	Yield	Volatility	Momentum	Quality	Liquidity
2019Q1-2019Q2	0.9753	0.9062	0.9060	0.8816	0.6954	0.9725	0.8816
2019Q2-2019Q3	0.9839	0.8953	0.9079	0.8265	0.7432	0.9727	0.9008
2019Q3-2019Q4	0.9472	0.9227	0.9257	0.8462	0.6979	0.9802	0.8926
2019Q4-2020Q1	0.8608	0.8613	0.8793	0.6537	0.8043	0.9171	0.8510
2020Q1-2020Q2	0.9115	0.8686	0.8728	0.7781	0.6446	0.9547	0.8983
2020Q2-2020Q3	0.9747	0.8977	0.8692	0.8550	0.7959	0.9654	0.8924
2020Q3-2020Q4	0.9689	0.7600	0.8986	0.8205	0.8380	0.9821	0.8831
2020Q4-2021Q1	0.8864	0.9048	0.9167	0.8435	0.7191	0.9677	0.9025
2021Q1-2021Q2	0.9850	0.8759	0.8867	0.8639	0.7278	0.9746	0.8940
2021Q2-2021Q3	0.9457	0.8950	0.9069	0.8343	0.7466	0.9694	0.8837
2021Q3-2021Q4	0.9862	0.9194	0.9300	0.8567	0.7435	0.9823	0.9119
2021Q4-2022Q1	0.9641	0.9081	0.9281	0.8190	0.7330	0.9645	0.8751
2022Q1-2022Q2	0.9777	0.8861	0.9021	0.9132	0.7402	0.9739	0.8656

Source: Morningstar Quantitative Research.

Risk Model Applications

In this section, we demonstrate some application of the Risk Model. The North America Standard Model offers users the ability to decompose risk or attribute returns to factors and holdings through time and across many instruments. Morningstar also offers a full complement of scenario-analysis capabilities including historical scenarios, predefined macrofinancial scenarios, or market-driven scenarios.

Factor Attribution and Risk Decomposition

The Morningstar North America Industry Standard Model allows investors to see and quantify the contribution from various factors to their portfolio's performance. Factor attribution is a technique used

to understand the relative importance of different factors in explaining the portfolio performance. The technique involves decomposing the portfolio returns into different factors, such as industry exposures and style exposures. By identifying which factors are driving returns, investors can adjust their portfolio to either increase exposure to desirable factors or reduce exposures to undesirable ones. This will also allow them to determine any unexpected exposures and differentiate between performance from systematic risk. Excess returns from the model are decomposed to active risk factor exposures, into factor risks (systematic), and an investment-specific risk (stock selection). The factor risks can be further decomposed across the individual systematic factors from the model. Exhibit 8 illustrates the factor attribution of SPY from the North America model. In November 2022, SPY had a total active return of 0.15%. The majority of the return is contribution from the market itself since it is a market index ETF.

Exhibit 9 Factor Attribution

Period	01/01/2023-01/31/2023			12/01/2022-12/31/2022			11/01/2022-11/30/2022		
Contribution %	Portfolio	Benchmark	Active	Portfolio	Benchmark	Active	Portfolio	Benchmark	Active
Total Return	6.29	6.70	0.42	5.76	5.81	0.06	5.56	5.41	0.15
Risk Free Return	0.31	0.31	0.00	0.38	0.38	0.00	0.31	0.31	0.00
Investment Specific	-1.07	-0.98	-0.09	-1.98	-1.82	-0.16	-3.41	-3.28	-0.13
Factor Total	7.04	7.37	-0.33	-4.15	-4.37	0.22	8.66	8.38	0.28
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Style	-0.20	-0.02	-0.17	0.11	0.00	0.11	0.78	0.48	0.30
Size	-0.12	-0.07	-0.05	0.04	0.02	0.02	0.61	0.35	0.26
Style	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.03	0.02
Yield	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
Volatility	-0.04	-0.02	-0.02	0.10	0.06	0.05	0.13	0.07	0.07
Momentum	-0.07	0.01	-0.08	0.01	0.00	0.01	-0.04	0.00	-0.04
Quality	0.00	0.00	0.00	-0.02	-0.01	-0.01	0.06	0.04	0.03
Liquidity	0.03	0.06	-0.03	-0.03	-0.07	0.04	0.03	0.05	-0.02
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Sector	-0.41	-0.25	-0.15	-0.24	-0.33	0.09	-0.80	-0.80	0.00
Basic Materials	0.05	0.05	0.00	0.05	0.05	0.00	0.12	0.13	-0.01
Communication Services	0.17	0.16	0.01	0.33	0.31	0.02	0.63	0.58	0.04
Consumer Cyclical	0.40	0.44	-0.04	-0.14	-0.16	0.02	0.27	0.30	-0.03
Consumer Defensive	-0.65	-0.60	-0.05	0.17	0.15	0.01	-0.23	-0.22	-0.02
Healthcare	-0.99	-0.96	-0.04	0.39	0.38	0.01	-0.38	-0.36	-0.01
Industrials	-0.07	-0.07	0.00	0.10	0.10	0.00	0.07	0.07	0.00
Real Estate	-0.02	-0.02	0.00	-0.02	-0.02	0.00	-0.09	-0.09	0.01
Technology	0.76	0.78	-0.02	-0.98	-1.00	0.03	-0.72	-0.73	0.02
Energy	0.08	0.08	0.00	-0.14	-0.14	0.00	-0.29	-0.30	0.01
Financial Services	0.15	0.15	0.00	-0.11	-0.11	0.00	-0.14	-0.14	0.00
Utilities	-0.27	-0.26	-0.01	0.12	0.11	0.00	-0.04	-0.04	0.00
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Region	7.64	7.65	0.00	-4.02	-4.04	0.02	8.68	8.70	-0.02
Equity Market	7.64	7.65	0.00	-4.02	-4.04	0.02	8.68	8.70	-0.02

Source: Morningstar Quantitative Research.

Another key feature of the North America Standard Model is risk decomposition. It involves analyzing the overall risk, identifying the various factors that contribute to it, and then breaking them down into smaller components. The purpose of risk decomposition is to identify the specific areas of risk that require the most attention and to develop strategies for addressing them. By breaking down total risk into smaller sub-risks, it becomes easier for investors to assess and manage each individual component. Exhibit 10 showcases a three-month period risk decomposition for SPY from November 2022 to January 2023. As expected, most of the risk for SPY is the equity market risk, which accounts for almost 96% of the total risk. SPY invests in companies across various sectors. Sector accounts for 3.36% of the total risk, with 20% coming from the technology sector. Idiosyncratic risk accounts for 1.78% of the total risk, which indicates that the factors from the North America model successfully explain more than 98% of the risk. In summary, the majority of SPY's risk comes from market risk with a small contribution from sector risk.

Exhibit 10 Risk Decomposition

Period	11/01/2022 - 01/31/2023	
	Contribution to Total Risk	Contribution to Total Risk %
Total Risk	**18.12**	**100.00**
Total Factor Risk	17.96	98.22
Idiosyncratic Risk	2.42	1.78
–	–	–
Factors	–	–
Region	17.40	96.01
Equity Market	17.40	96.01
--	--	--
Sector	0.61	3.36
Technology	3.48	19.23
Consumer Cyclical	0.18	0.98
Energy	0.18	0.97
Basic Materials	-0.01	-0.03
Real Estate	-0.08	-0.46
Industrials	-0.14	-0.78
Utilities	-0.29	-1.61
Financial Services	-0.34	-1.89
Communication Services	-0.35	-1.96
Consumer Defensive	-0.93	-5.12
Healthcare	-1.08	-5.97
--	--	--
Style	-0.21	-1.15
Liquidity	0.10	0.58
Quality	0.04	0.22
Yield	0.00	0.02
Style	-0.00	-0.00
Size	-0.03	-0.18
Momentum	-0.15	-0.84
Volatility	-0.17	-0.95

Source: Morningstar Quantitative Research.

Factor-Mimicking Portfolio

Examining the composition of the factor-mimicking portfolios generated by the Risk Model can give us granular insight into the style factors. A factor-mimicking portfolio is a long-short portfolio of securities with unit exposure to the particular factor and zero exposure to all other factors. The cross-sectional

constrained regression in the Risk Model (see Appendix C) produces such factor-mimicking portfolios and the returns of these portfolios. The risk model exposures provide rankings of the weight of stocks on both long position and short position within each factor. The long-short portfolio strategy is an investment technique that involves simultaneously buying securities that are expected to increase in value and selling securities that are expected to decrease in value. By design, factors are long-short portfolios. For example, a value-growth long-short portfolio combines long position in value stocks and short position in growth stocks. The objective of this portfolio is to generate positive returns by capturing the performance of value stocks and hedging against the downside risk of growth stocks.

For the North America Standard Model, we utilized Morningstar Equity Style Box methodology to calculate style scores. Value stocks are companies that are undervalued by the market, characterized by price/earnings, price/book, price/cash flow, price/sales, and dividend yield. Growth stocks, on the other hand, are companies that are expected to grow at a faster rate than the overall market, defined by long-term earnings growth, book value growth, sales growth, cash flow growth, and earnings growth.

For investors, there are several potential benefits of factor-mimicking portfolios. The first one is diversification. By investing in multiple factors, investors can reduce the risk of their portfolio and achieve greater diversification.

The second potential benefit is lower cost. Factor-mimicking portfolios can be constructed using passive investment strategies, such as index funds or ETFs, which tend to have lower fees and expenses compared with actively managed funds.

The third benefit is its transparency. Factor-mimicking portfolios are constructed based on well-defined investment factors, which make them more transparent than actively managed funds. Investors can better understand the risks and potential returns associated with these portfolios.

The fourth advantage of a factor-mimicking portfolio is its customization. Investors can create factor-mimicking portfolios that align with their specific investment objectives and risk tolerance. This customization can help investors achieve their financial goals more effectively.

Overall, factor-mimicking portfolios can be a useful tool for investors who want to capture the benefits of specific investment factors while maintaining a diversified and low-cost portfolio. Next, we will showcase the top10 value and growth stocks.

Here are the top 10 stocks for value and growth factor, respectively.

Exhibit 11 Top 10 Value Stock Holdings

Rank	Company Name	Symbol	Country	Sector
1	Berkshire Hathaway	BRK.A	USA	Financial Services
2	AT&T	T	USA	Communication Services
3	Pfizer	PFE	USA	Healthcare
4	Verizon Communications	VZ	USA	Communication Services
5	Apple	AAPL	USA	Technology
6	Intel	INTC	USA	Technology
7	General Motors	GM	USA	Consumer Cyclical
8	CVS Health	CVS	USA	Healthcare
9	Comcast	CMCSA	USA	Communication Services
10	AbbVie	ABBV	USA	Healthcare

Source: Morningstar Quantitative Research.

Exhibit 12 Top 10 Growth Stock Holdings

Rank	Company Name	Symbol	Country	Sector
1	Tesla	TSLA	USA	Consumer Cyclical
2	Booking Holdings	BKNG	USA	Consumer Cyclical
3	Marriott Intl	MAR	USA	Consumer Cyclical
4	Mastercard	MA	USA	Financial Services
5	Eli Lilly	LLY	USA	Healthcare
6	Exxon Mobil	XOM	USA	Energy
7	Nu Holdings	NU	BRA	Financial Services
8	Hilton Worldwide Holdings	HLT	USA	Consumer Cyclical
9	Prosus	PRX	NLD	Communication Services
10	Snowflake	SNOW	USA	Technology

Source: Morningstar Quantitative Research.

We look at the example of top 10 value and growth within the factor. The top 10 value stocks include companies such as Berkshire Hathaway, AT&T, Pfizer, and so on. The top value stocks are across various sectors, such as consumer cyclical, financial services, energy, technology, and so on. These companies have strong fundamentals and are expected to provide long-term benefit for investors. The top 10 growth stocks include companies such as Tesla, Booking Holdings, Marriott, and so on. One interesting finding is that there are several hotel industry companies in the growth stock list. The reason is that the

style scores are calculated based on the fiscal year. The hotel industry had tremendous growth after the authorities lifted the COVID-19 lockdown policy.

Conclusion

The Morningstar North America Industry Standard Model aims to model the risk of assets and portfolios that lies in the North American region. There are 18 style and sector factors to help investors understand market phenomena and/or equilibrium asset and portfolio prices utilizing Morningstar's unique holding information.

The model monitors factor exposures and provides insight on economic and financial situations regarding factor exposures. Our aim has been to emphasize interpretability, responsiveness, and predictive accuracy, and in doing so, we believe we have developed a unique framework for building risk models.

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Appendix A: Risk Model Definition

Morningstar North America Standard Factor Model

The Morningstar North America Standard Factor Model captures risk premiums across the North America region.

Factors

The model is defined by 19 factors across style, sector, currency, and equity market.

- Equity Market Factor
- Style: Yield, Size, Volatility (standard model), Quality, Liquidity, Value-Growth (standard model), Momentum
- Sector: Basic Materials, Energy, Financial Services, Consumer Defensive, Consumer Cyclical, Technology, Industrials, Healthcare, Communication Services, Real Estate, Utilities

Data Availability

The model generates daily data from Jan. 1, 2006, to the present day.

Currency

The model is available in U.S. dollar and Canadian dollar.

Appendix B: Equity Factor Definitions

Style Factor Definition

Size

The size factor is the normalized value of the logarithm of a firm's market capitalization:

$$size_{i,t} = -ln(MV_{i,t})$$

The factor is unbounded, and higher scores indicate smaller market capitalization. A score of 0 indicates an average level of market capitalization.

Liquidity

The liquidity factor is the normalized value of the stock's raw share turnover. The raw share turnover score is calculated as the logarithm of the average trading volume divided by shares outstanding over the past 30 days. It is essentially a churn rate for a stock and represents how frequently a stock's shares get traded.

$$share\ turnover_{i,t} = ln\left(\frac{1}{T}\sum_{t=1}^{T}\frac{V_{i,t}}{SO_{i,t}}\right),\ where\ T = 30$$

The factor is unbounded, and higher scores indicate higher liquidity. A score of 0 indicates an average level of liquidity.

Value-Growth (standard model)

Value-growth reflects the aggregate expectations of market participants for the future growth and required rate of return for a stock. For this version used in the standard factor model, we use the raw style score from the Style Box as the input for calculating the value-growth exposure of stocks. The raw style score is calculated as the difference between a stock's growth score and value score:

$$Raw\ Style\ Score = Growth\ Score - Value\ Score.$$

The value score is the weighted average of a stock's prospective earnings (E), book value (BV), revenue (R), cash flow (CF), and dividend (D), all scaled by the current price of the stock:

$$Value\ Score = \left[w_E \times \frac{E}{P_t} + w_{BV} \times \frac{BV}{P_t} + w_R \times \frac{R}{P_t} + w_{CF} \times \frac{CV}{P_t} + w_D \times \frac{D}{P_t}\right].$$

The growth score of a stock is the weighted average of the growth rates in a company's earnings (E), book value (BV), revenue (R), and cash flow (CF):

$$Growth\ Score = \left[w_E \times E_{growth} + w_{BV} \times BV_{growth} + w_R \times R_{growth} + w_{CF} \times CF_{growth}\right].$$

The factor is unbounded, and higher scores indicate higher growth expectations and less value exposure. A score of 0 is average. For more details, refer to the Morningstar Style Box Methodology listed in the References section.

Momentum

The momentum factor is the normalized value of the stock price's raw momentum score. The raw momentum score is calculated as the cumulative return of a stock from 365 calendar days ago to 30 days ago. This is the classical 12-1 momentum formulation except using daily return data as opposed to monthly. To compute, U.S. dollar currency returns are used.

$$momentum_{i,t} = \sum_{t-365}^{t-30} \left(ln(1 + r_{i,t}) - ln(1 + rf_t) \right)$$

The factor is unbounded, and higher scores indicate higher returns over the past year as well as a propensity for higher returns in the future. A score of 0 indicates an average level of momentum.

Volatility (standard model)

The firm-specific volatility is a combination of three standardized volatility proxies:

$$Volatility\ Composite = 50\% * IVOL_z + 25\% * TVOL_z + 25\% * MAX5_z$$

(1) IVOL (six-month horizon, 50%):
Idiosyncratic volatility (IVOL) is the capital asset pricing model's (CAPM) residual volatility over the past six months. We estimate a time-series regression of excess daily stock return against the value-weighted excess daily market return of the estimation universe. The IVOL is the standard deviation of the CAPM residuals. We standardize IVOL to obtain its z-score.

$$CAPM: r_{i,t} - r_{ft} = \alpha_{i,t} + \beta_t \left(r_{m,t} - r_{ft} \right) + \varepsilon_{i,t}$$
$$IVOL: \sigma_{i,t} = std(\varepsilon_{i,t})$$

(2) TVOL (six-month horizon, 25%):
Total volatility (TVOL) is defined as the volatility of a stock's daily returns over the past six months. We standardize TVOL to obtain its z-score.

$$TVOL = \sqrt{\frac{\sum_{t=1}^{N} (r_t - \bar{r_t})^2}{N - 1}}$$

(3) MAX5 (one-month horizon, 25%):
MAX5 is defined as the average of the highest five daily returns over the past one month. We standardize MAX5 to obtain its z-score.

The factor is unbounded, and higher scores indicate higher volatility. A score of 0 indicates an average level of volatility.

Quality

We define a quality score of a stock as the equally weighted z-score of a company's profitability (trailing 12-month return on equity) and the z-score of its financial leverage (trailing 12-month debt/capital). The z-score is with respect to all the stocks in the global universe.

$$Quality = \frac{1}{2}\left[ROE_z + \left(1 - \frac{Total\ Debt_t}{Total\ Capital_t}\right)_z\right].$$

where ROE is the trailing 12-month return on equity and the subscript z indicates a z-score.

The factor is unbounded, and higher scores indicate higher quality. A score of 0 indicates an average level of quality.

Yield

The yield factor is as a total yield, which is the sum of trailing 12-month buyback and dividend yield of a company. Higher values indicate larger, positive yield exposure:

$$Total\ Yield = Buyback\ Yield_{ttm} + Dividend\ Yield_{ttm}$$

The factor is unbounded, and higher scores indicate higher yield. A score of 0 indicates an average level of quality.

Sector Factor Definition

Sector exposures are calculated based on a time-series regression of excess stock returns to a set of sector benchmarks.

$$r_t^i - r_t^f = \alpha^i + \beta_1^i\left(r_t^1 - r_t^f\right) + \cdots + \beta_k^i\left(r_t^k - r_t^f\right) + \varepsilon_t^i$$

$$r_t^i = weekly\ return\ on\ the\ ith\ stock$$

$$r_t^f = weekly\ return\ on\ 3-mo\ US\ TBill$$

$$r_t^k = weekly\ return\ on\ the\ kth\ sector\ benchmark\ (for\ example, Basic\ Materials)$$

$$constraints: 0 < \beta_k^i < 1; \sum_k \beta_k^i = 1$$

Benchmark Construction

Sector benchmark returns are calculated using a market-cap-weighting scheme using stocks from our estimation universe. Stocks are assigned to sectors on the basis of Global Sector ID. All returns are computed in U.S. dollars. Market capitalizations were also converted to dollars prior to benchmark constitution.

Regression Setup

Regressions are five years in length and are run on a rolling, weekly frequency. In the case where a stock does not have five years of history, we run the time-series regression back to the inception date. If a stock has less than one year of history, we do not run the regression and instead default to the stock's Morningstar sector classification. We employ a Bayesian prior probability that presupposes that companies should be entirely exposed to the sector to which they are assigned.

Interpretation

Sector exposures are bounded between 0 and 1. They must jointly (including the intercept) sum to 1. Higher scores indicate higher levels of sensitivity to individual sectors.

Appendix C: Cross-Sectional Regression

After deciding on the universe of securities to include in the model and gathering quality input data, the next important step in risk model construction is to run the cross-sectional regression. There are numerous techniques and specifications we can employ in the regression; the following method has been chosen to provide accurate, meaningful, and stable estimates of factor premiums. Special care has been given to deal with the common multicollinearity issue associated with sector factors. As the sum of all sectors are both the entire universe of securities, it is difficult to estimate the pure sector effects that are uncorrelated with each other. We apply a constrained regression to disentangle the sector effects from each other, as well as from the overall market movement.

The Constrained Regression

The return of a security r_i in the cross section can be explained as

$$r_i = \alpha + \sum_{m=1}^{M} X_{i,m} f_m^{Style} + \sum_{s=1}^{S} X_{i,s} f_s^{Sector} + \varepsilon_i \ (E1)$$

where $X_{i,m}, X_{i,s}$ are security i's exposure to style factor m, sector s;
$f_{\mathrm{m}}^{Style}, f_s^{Sector}$ are factor premiums for style m, sector s; M, S are the total number of style and sector factors in a particular model; α is the intercept; and ε_i is the residual term, representing a stock's specific return.

In the estimation, the market-cap-weighted average sector premiums and region premiums are both constrained to zero:

$$\sum_{s=1}^{S} u_s f_s^{Sector} = 0 \ (E2)$$

where u_s and $\mathrm{v_r}$ are the market-cap weights of sector s, respectively. This means certain sectors earn positive returns and others earn negative, but the market-cap-weighted average sector returns are zero.

To understand the logic of these constraints, imagine an investor who has a portfolio that has the same sector composition as the entire market; the sector average return from this portfolio should not contribute extra return to the market because the sum of sectors is the market. But what captures the market return in this setting? It turns out that under certain conditions, the estimated α is a good proxy for the market.

The Equity Market Factor

The intercept is represented by a column of 1 in the exposure table, and it can be viewed as stocks' exposure to a factor. To what factor does every stock have the same level of exposure? It should be a factor that represents the equity market universe, and an exposure of 1 indicates membership in this universe. For this reason, the estimated α can approximate the overall equity market return; we name it the "equity market factor." The approximation becomes accurate with some additional conditions.

In addition to the constraints on sector premiums, all style factor exposures are standardized cross-sectionally to have a market-cap-weighted mean of zero:

$$\tilde{X}_m = \sum_{i=1}^{N} w_i X_{i,m} = 0 \quad (E3)$$

where
$\tilde{X}_m$ = market-cap-weighted average exposure of the estimation universe to factor m,
w_i = market-cap weight of security i,
$X_{i,m}$ = security i's exposure to style factor m.

This standardization ensures the overall market is style-neutral. Now, consider aggregating the market-cap-weighted estimation universe as

$$r_E = \alpha + \sum_{m=1}^{M} \tilde{X}_m f_m^{Style} + \sum_{s=1}^{S} u_s f_s^{Sector} + \sum_{i}^{N} w_i \varepsilon_i \quad (E4)$$

where r_E is the market-cap-weighted average return. Note, by equations (E2) and (E3), the second-to-the-fourth items on the right-hand side become zero. The last term of weighted residuals equals zero because in a least-squares estimation, the residual term is orthogonal to the independent variables including the intercept of 1s. Therefore, the estimated α can approximate closely the market-cap-weighted average return of the estimation universe.

Note that the regression has been weighted using the square root of the market-cap weight of each stock in the estimation universe. This is to reduce the uneven variability of the specific returns among stocks, which improves the statistical properties of premium estimates. In this case, the weighted sum of residuals in equation (E4) is only approximately zero.

To sum up, with the constrained regression, the sector premiums measure the pure and uncorrelated sector returns relative to the overall market return, captured by α. $\alpha + f_s^{Sector}$ approximates the return of a geographically diversified portfolio of companies in sector s.

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For More Information

+1 312 244-7541
lee.davidson@morningstar.com

22 West Washington Street
Chicago, IL 60602 USA